DOCUMENT RESUME

ED 129 633 SE 021 541

AUTHOR Fennema, Elizabeth; Sherman, Julia
TITLE Sex-Related Differences in Mathematics Learning: Myths, Realities and Related Factors.
PUB DATE 76
NOTE 24p.; Paper presented at the annual meeting of the American Association for the Advancement of Science (Boston, Massachusetts, February 22-23, 1976); Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS *Achievement; Attitudes; Elementary Secondary Education; Learning; *Mathematics Education; *Research Reviews (Publications); *Sex (Characteristics); Sex Differences; *Student Characteristics

ABSTRACT

Research concerned with differences in mathematical achievement of males and females is discussed in this document. Variables hypothesized to be related to achievement of women in general and to mathematics learning and studying in particular are considered: verbal ability; spatial visualization ability; confidence in learning mathematics; mathematics as a male domain; attitude toward success in mathematics; perceived attitudes of mother, father, and teachers toward one as a learner of mathematics; usefulness of mathematics; and effectance motivation in mathematics. Four conclusions are drawn: (1) sex-related differences in mathematics achievement are not universal, (2) many fewer females than males study mathematics in eleventh and twelfth grades, (3) the relationship between cognitive factors and differential learning learning of mathematics by the sexes is unclear, and (4) differential mathematics studying and mathematics achievement by the sexes is at least partially caused by socio-cultural factors mediated through sex-role expectations. (DT)

# SEX-RELATED DIFFERENCES IN MATHEMATICS LEARNING: MYTHS, REALITIES AND RELATED FACTORS

Elizabeth Fennema and Julia Sherman
The University of Wisconsin-Madison

Paper presented at the American Association for the Advancement of Science, Boston, 1976, in a Symposium entitled "Women and Mathematics."

Sex-Related Differences in Mathematics
Learning: Myths, Realities and Related Factors

Is the belief that males learn mathematics better than do females an eternal truth, a changing phenomenon, or a myth? One has only to look at the most recent book on sex differences, i.e., The Psychology of Sex Differences by Maccoby and Jacklin (1974) or many newspapers quoting the results of the National Assessment of Educational Progress (NAEP) to seemingly find confirmation that males are superior in mathematics. Maccoby and Jacklin conclude that one "sex difference that (is) fairly well established" is "that boys excel in mathematical ability" (pp. 351-352). A press release from NAEP states: "In the mathematics assessment, the advantage displayed by males, particularly at the older ages, can only be described as overwhelming." (Mullis, 1975, p. 7).

However, a recent review of the literature reported during the last 15 years or so offers a more modified conclusion:

> "No significant differences between boys' and girls' mathematical achievement were found before boys and girls entered elementary school or during early elementary years. In upper elementary and early high school years significant differences were not always apparent. However, when significant differences did appear they were more apt to be in the boys' favor when higher-level cognitive tasks were being measured and in the girls' favor when lower-level cognitive tasks were being measured. No conclusion can be reached concerning high school learners." (Fennema, 1974, pp. 136-137)

A similar conclusion is also reached by Callahan and Glennon (1975).

There are indeed many reasons to doubt the validity of the belief that males are superior to females in mathematical ability. Any generalization as sweeping as this one is suspect from the start. Are all males superior to all females? (A ridiculous question that needs no answer.) Is the mean performance of groups of males superior to the mean performance of groups of females at all ages on all kinds of tests? (A doubtful proposition!) What is meant by Maccoby and Jacklin's

statement that boys excel in mathematical ability? Is this an innate capacity they are referring to or is it mathematical achievement which reflects opportunity to learn? Do groups of male and females who have had the same opportunity to learn mathematics, evidence differences on tests measuring what they have learned? If differences found between male and female performance are statistically significant, are they also educationally significant? Is the difference in mean performance on tests of mathematical achievement a stable difference or is it something that is changing as society and one of its institutions--Education--changes?

There are no answers to some of these questions but there are also no eternal truths about the intellectual performance of human beings. It is imperative that scholars examine carefully those ideas that have been accepted as "truth." The belief that males are superior to females in mathematical ability is one of these truisms that must be examined.

A study funded in 1974-75 by the National Science Foundation does give some new insight on the question of sex-related differences in mathematical achievement between high school males and females (Fennema & Sherman, in press, a). During February and March of 1975, 589 females and 644 males selected by mathematics classes from all Madison, Wisconsin, public high schools, were given several tests including a standardized achievement test (Scannell, 1972). These students were enrolled in college preparatory mathematics classes appropriate for their grade, e.g., 9th grade algebra, 10th grade geometry, 11th grade algebra/trigonometry or pre-calculus, 12th grade advanced algebra or calculus. An analysis of variance computed on the achievement scores using school, sex, and grade as variables showed a significant sex effect in favor of males. Because a significant sex x school interaction was also found, data were analyzed separately for each high school. In only two schools were significant sex-related differences in math

achievement found and these differences in favor of males were about two test items at each grade level. These findings suggest that the existing opinion that females have less capacity for mathematics needs to be modified. Differences between male and female groups in mathematics achievement were very small. These differences were not more pronounced with increasing grade level and more difficult material.

However, there continues to be fewer females than males who elect to study mathematics. A detailed study of participation in mathematics classes of the Madison, Wisconsin high schools was made concurrently with the study reported above (Sherman & Fennema, in press). Table 1 shows the percentage of males and females enrolled in grade-typical mathematics courses. More males than females were enrolled in General Mathematics--a terminal math course. By 11th grade a higher percentage of males were enrolled at each school and the difference was greater at the 12th grade. It is clear that many more males than females studied math in the 11th and 12th grade, although substantial numbers of females did study math in the 11th grade. However, Madison is considered a liberal, intellectual city. It is likely that the discrepancy by sex in enrollment in mathematics courses is even greater in other locales.

- - - - - - - - - - - - - - - -

Place Table 1 About Here

- - - - - - - - - - - - - - - -

Does this trend continue in higher education? Data from the University of Wisconsin-Madison provide some insight. In the Fall of 1975 there were 818 males and 257 females enrolled in the first semester of the more advanced calculus sequence--a ratio of about 3 males to 1 female. Enrolled in the third semester of the sequence were 431 males and 72 females--a ratio of 6 males to 1 female. Approximately 53% of the males who started this sequence studied math at least 3 semesters while only 28% of the females continued for 3 semesters. The number of females who started studying university math was lower than the number of males

and the continuation rate was higher for males (Mathews, 1976). In 1975 there were 45 female and 130 male undergraduate mathematics majors. There were 15 female and 164 male graduate students in mathematics. There was one female and 59 male tenured faculty members in the Mathematics Department (Miles, 1976). These data suggest that the gap in studying mathematics evident in 11th grade widens indefinitely.

Data such as the above are interesting and useful for consciousness raising. Of more importance, however, is information concerning why this differential studying of mathematics and sometimes differential achievement in mathematics exists. It has been suggested (Stafford, 1972) that quantitative ability is transmitted as a recessive characteristic on the X chromosome. If one accepts this hypothesis, it follows that fewer females are inherently as capable as males to learn mathematics. Although other prominent authorities (Maccoby and Jacklin, 1974) say that the evidence in this area is inconclusive, the inheritance of quantitative ability as an explanation of females' less adequate mathematical performance appears only to be of theoretical interest for at least two reasons. First, the best predictors of success in mathematics are previous mathematical learning and general intelligence. As there are no significant sex-related differences in general intelligence and until about adolescence no significant differences in mathematical achievement scores, the number of females who have equal capability with males for learning high school mathematics is much larger than the number of females who elect to study mathematics in late high school and college. Second, even considering the differences found in male-female average mathematical performance, the performance distributions are not nearly so different as are the distribution of the sexes in mathematics/science careers. Clearly, influences other than those associated with heredity must be affecting females' mathematics learning and usage.

Table 1

Percentage of Boys and Girls
in "On-grade" Math Classes[a]

| | School | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | |
| Grade | F | M | F | M | F | M | F | M |
| 9[b] | 06 | 11 | 25 | 31 | 21 | 28 | 16 | 25 |
| 9[c] | 81 | 82 | 71 | 69 | 76 | 74 | 88 | 77 |
| 10 | 61 [redacted] | 59 [redacted] | 51 | 50 | 62 | 65 | 40 | 36 |
| 11 | 36 | 43 | 24 | 32 | 30 | 34 | 22 | 23 |
| 12 | 12 | 20 | 04 | 15 | 11 | 23 | 03 | 05 |

[a]Percentage obtained by dividing number of each sex enrolled in an "on-grade mathematics class by enrollment of that sex in that grade. The two sets of data were not obtained on the same day so percentages may be slightly inaccurate.

[b]General Mathematics

[c]Algebra

Many cognitive and socio/cultural factors have been hypothesized to be related to achievement of women in general and to mathematics learning and studying in particular. Two cognitive variables and eight socio/cultural variables which appear the most salient will be discussed here and new information concerning them will be presented.

## COGNITIVE VARIABLES

### Verbal Ability

One ability, strongly related to performance in mathematics, is verbal ability (Aiken, 1971). Some believe that girls have greater verbal ability than boys (Maccoby and Jacklin, 1974, p. 351). This is a peculiar situation. Verbal skills are highly important in mathematics learning; girls are better at verbal skills than boys; then why aren't girls better at mathematics than boys? Part of the explanation at least lies in the fact that the conclusion about sex-related verbal skills is also an overgeneralization. Those male and female students who elect to continue studying mathematics (a highly select group) probably do not exhibit any differences in verbal skills. The 1975 NSF study showed no strong difference in verbal ability between the two sexes. Although verbal ability was highly related to mathematics ($r = .49$ for females, $r = .47$ for males), differences in verbal ability did not explain differential studying and learning of mathematics.

### Spatial Visualization Ability

Male superiority in spatial tasks is another long accepted "truth" and another one which is changing as more and better data are available. In 1966 Maccoby concluded that "by the early school years boys consistently do better on spatial tasks, and this difference continues through the high school and college years." (Maccoby, 1966, p. 26). In 1974 Maccoby sharply restricted her conclusion of

male superiority on all types of spatial tasks and moved the age of its appearance to adolescence when she and Jacklin stated: "Male superiority on visual-spatial tasks is fairly consistently found in adolescence and adulthood, but not in childhood." (Maccoby and Jacklin, 1974, p. 351).

Spatial visualization tasks are logically related to mathematics. Tasks measuring spatial visualization require that objects be rotated, reflected or translated--all important geometrical ideas. In fact James and James (1968, p. 162) in defining geometry as "the science that treats of the shape and size of things, . . . the study of invariant properties of given elements under specified groups of transformations" are describing accurately most conditions met by items on spatial visualization tests. Although logical relationship can be seen between spatial visualization ability and mathematics, empirical data supporting such a relationship is hazy at best (Fennema, in press). However, sex-related differences in spatial visualization tasks become more pronounced during adolescence and since sex-related differences in math study and perhaps achievement also become more pronounced during this time span, spatial visualization skills may partly account for the differential mathematics learning (Sherman, 1967). In the 1975 NSF study, significantly higher spatial visualization scores in favor of males were found in only two of the high schools. Correlations between spatial visualization and math achievement were .45 for females and .51 for males indicating a strong relationship that was similar for males and females. In one of the two high schools where a sex-related difference was found, a sex-related difference in spatial visualization ability was found. In this school the difference in math achievement was eliminated when the difference in spatial visualization was covaried out. While the NSF data does indicate that spatial visualization ability and math achievement are related, this variable didn't appear to differentiate sharply between males and females.

It is interesting to speculate on the effects of spatial visualization ability on the learning of mathematics by younger children. The students in the NSF study were high school students who had been studying mathematics for 8-11 years. No one knows what the effect of differential spatial ability would have been on these students' previous learning of math. Smith (1964) hypothesizes that it is in advanced mathematics, i.e., late high school or college math, that spatial ability becomes highly important. On the other hand, Fennema (in press) hypothesizes that it is when mathematical ideas are first introduced (when learners are at the pre-operational or concrete operational stage) that spatial ability is important. If the latter hypothesis has validity, then the effect of sex-related differences in spatial ability would have already had an effect on the ability to learn advanced math and could result in lower achievement scores for girls and/or unwillingness to take more math.

Existing evidence suggests that the sex-related differences in studying and learning math cannot be explained fully by any differences in cognitive abilities between the sexes. Even the small differences in performance on spatial visualization tasks cannot account for the very large discrepancy between males and females who study math. Therefore attention must be given to that wide range of variables identified as socio/cultural or affective factors.

## AFFECTIVE FACTORS

Socio/cultural or more precisely speaking affective variables deal with feelings, interests, attitudes, appreciation, values, and emotional sets or biases (Krathwohl, et.al., 1964). Obviously some of this infinite set of variables affect not only one's choosing to study mathematics, but the amount of effort one is willing to exert to learn. It is also obvious that it is risky at best to discuss such variables as if they were discrete. One's feelings, attitudes, etc., are determined by the interaction of many influences including cognitive and

physiological, as well as situational variables. However, it is also impossible to deal in any understandable way with the totality of behavior. Therefore, eight affective variables have been selected for discussion. These eight variables have been hypothesized either to be directly related to the learning of mathematics or to differential motivation to achieve by females and males. New information is also available from the 1975 NSF study concerning the relationship of these eight variables to the learning and studying of mathematics (Fennema & Sherman, in pressa; Sherman & Fennema, in press). Domain specific Likert-type scales were constructed to measure each of the eight affective variables discussed (Fennema & Sherman, in pressb). For each school, sex X grade ANOVAS were performed for each scale. Table 2 tallies significant sex effects for the affective and cognitive variables and Table 3 shows the correlations between these variables and mathematics achievement. The theoretical basis for the significance of each variable will be discussed before the new data are presented.

Put Tables 2 & 3 About Here

Confidence in Learning Mathematics

What one believes about oneself bears a significant relationship to the way one behaves. The importance of academic self-concept in learning mathematics is being increasingly recognized. Crandall (et.al., 1962) concluded that girls underestimate their own ability to solve mathematical problems. Others have concluded that females feel inadequate when faced with a variety of intellective, problem-solving activities (Kagan, 1964), and are less likely to expect success than males (Frieze, 1975). Maccoby and Jacklin (1973) reported that "girls tend to underestimate their own intellectual activities more than boys do." If one feels inadequate in mathematics, one would probably tend to avoid the study and

Table 2

Significant Sex-Related Differences[a]

| | School | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Mathematics Achievement[b] | X | | | X |
| Verbal Ability | | | | |
| Spatial Visualization | | X | | X |
| Confidence in Learning Mathematics | X | | X | X |
| Mother[c] | X | | X | X |
| Father[c] | X | | | X |
| Teacher[c] | | | | |
| Attitude toward Success in Mathematics | | | | X |
| Math as a Male Domain | X | X | X | X |
| Usefulness of Mathematics | X | | | X |
| Effectance Motivation in Mathematics | | | | |

[a]Significant $<.05$. See Fennema & Sherman (in pressa) for complete discussion.

[b]In all instances except Attitude toward Success in Mathematics, males had higher scores, more positive attitudes. For Math as a Male Domain, males stereotyped math more as a male domain.

[c]Perceived attitude of mother, father or teacher toward one as a learner of mathematics.

Table 3

Average Correlation Coefficients:
Mathematics Achievement and Other Varaibles
Grades 9-11[a]

| Test | Female[b] | Male |
|---|---|---|
| Verbal Ability | .49** | .47** |
| Spatial Visualization | .45** | .51** |
| Confidence in Learning Mathematics | .40** | .41** |
| Math as a Male Domain | .21** | .07 |
| Attitude toward Success in Mathematics | .09* | .13** |
| Mother | .28** | .20** |
| Father | .24** | .23** |
| Teacher | .38** | .36** |
| Usefulness of Mathematics | .22** | .25** |
| Effectance Motivation in Mathematics | .26** | .31** |

[a]Correlations are reported in Fennema & Sherman, in pressa.

[b]$N$ = 555 for females, 574 for males.

*$p$ < .05

**$p$ < .01

practice of mathematics. If girls feel less adequate than boys in mathematics learning, it might partially explain differential achievement by the sexes.

The data from the NSF study gave some support to this idea. At three out of four schools males were significantly more confident of their ability to learn mathematics. This is rather a chicken and egg question. Was confidence the result or the cause of higher achievement? The two were moderately related ($r = .40$ or $.41$). At Schools 1 and 4 where sex-related differences in ahcievement were found, there were similar differences in confidence. However, at Sthool 2 significant differences in confidence but not in math achievement were found indicating that equal achievement between the sexes did not result in equal confidence in learning mathematics.

Mathematics as a Male Domain

The use and creation of mathematics has not been exclusively a male prerogative, but almost (Osen, 1974). It is reasonable to believe that if boys and girls see mathematics as something that is, and should be a male domain, then girls will not be motivated to learn mathematics as effectively as if mathematics is seen as a female or neuter activity. Stein and Smithells (1969) and Carey (1958) offer evidence that support the view that girls and boys see math as a male domain. Girls apparently have higher achievement motivation in areas that are perceived to be feminine in character (Stein & Bailey, 1973). Boys' beliefs in this area influence girls also, as Horner (1972) has offered evidence that girls even fear sanction from peer males for achievement in male domains.

At all four schools in the NSF study, males stereotyped math as a male domain significantly higher than did females. Girls showed less variance than boys in their attitude and appeared to deny that math is a male domain. A significantly higher correlation between this variable and math achievement was found for females

(r = .21) than for males (r = .07). This indicates that the degree to which girls stereotyped math as a male domain was significantly related to their math achievement. As one would expect, this was not true of boys.

Perceived Attitudes of Mother, Father, and Teacher toward One as a Learner of Mathematics

At least two sets of people influence learner's beliefs about whether mathematics is a masculine domain or whether mathematics should be learned, e.g., parents and teachers. If a girl perceives that these sets of people believe that mathematical activities are not important or not appropriate for females, then her incentive to learn mathematics will be lessened. Sells (1973) offers some evidence that these sets of people do differentially influence the sexes in relationship to mathematics achievement. Although one's perceptions of how others feel often are not totally accurate, such perceptions do influence behavior. If a person believes that significant others view mathematics as important for him or her, then he or she is more apt to strive to learn math.

Mothers and fathers treat boys and girls differently in a variety of ways which includes the learning of mathematics. Parents often think mathematics is more important and appropriate for boys than for girls and communicate this belief to their children. Parents reported that they bought more math related games for their sons (Hilton and Berglund, 1971); Block (1973) found that parents, especially fathers, expected more achievement from boys, and parents also offered more explicit rewards and reinforcement to their sons to learn math than to their daughters (Astin, 1974). At three out of four schools in the NSF study, boys perceived their mothers as being significantly more positive toward them as learners of mathematics. At two schools, boys felt their fathers had significantly more positive attitudes.

Teachers a so treat boys and girls differently. Although there is little direct evidence about teachers' behavior toward females and males in math classes, there is evidence that teachers interact more with boys than with girls (Meyer & Thompson, 1956) and that teachers reward boys more for creative behavior (Sears and Feldman, 1966; Torrance, 1963). Learners pick up cues from teachers as to what is appropriate behavior. If being creative (as problem-solving activity is) is more appropriate for boys than for girls, both sexes respond accordingly. If a teacher interacts more with boys than with girls, perhaps boys receive more help and as a result learn better. Teachers as role models are also important. During high school years and later, most mathematics teachers are male. This fact alone presents a powerful message to impressionable teenagers.

Interestingly there were no significant sex-related differences in perceived attitudes of teachers. That is, though perceived attitudes of teachers related moderately to achievement, the Teacher Scale scores were not different for the two sexes. These results were surprising because during pilot testing (n = 367), subjects had been asked to describe what had discouraged them most about the study of mathematics. About one-third of the girls specifically mentioned something related to teachers compared to about one-tenth of the boys. In Madison, 69% of the high school math teachers were male and they were more apt to be teaching the more advanced courses. This must have influenced how both male and female students felt about mathematics.

## Motive to Avoid Success in Mathematics

Since Horner (1968) first offered evidence that females--particularly high achieving females--fear success in male appropriate areas, much has been written about such a motive as an explanation of females' underachievement where it exists. In a simplistic way the theory goes something like this: In achievement

areas identified as male and in which females would be competing with males (e.g., medicine, law, business, math), some females with the capacity to perform at high levels will not do so because, if they are successful, they fear a variety of sanctions from males. Theoretically this motive operates increasingly during high school and college years. Some studies have supported this theoretical construct while others have not (Mednick and Weisman, 1974). Mathematics study and learning is logically an area that would be subject to the Motive to Avoid Success.

At only one school were significant differences found on Attitude toward Success with girls feeling more positive about being successful than did boys. This variable correlated very little with math achievement ($r = .09$ for females, .13 for males) which indicates that it is less important than other variables to the learning of math. However, results of a factor analysis (Fennema & Sherman, in pressa) showed that it did load with math as a male domain as a separate factor for females, but not for males. Thus, there was some indication of a special sex role factor for female mathematics learning, but not for males.

On the whole, however, these results apparently contradict Horner's hypothesis Some clarification is provided by the fact that there was a significant school X sex interaction such that the schools of higher socioeconomic status (Schools 1 and 3) showed girls having a less positive attitude toward success while at schools of lower socioeconomic status, less positive attitudes toward success in mathematic was found among boys. In other words the sex-related differences crisscrossed over socioeconomic status. This finding is consistent with one author's (Sherman, 1971) observation that academic learning in general is sex-typed male for higher SES classes and sex-typed female for lower SES classes. That is, Attitude toward Success in academic areas is probably class related; boys are more positive toward academic success in higher SES groups and girls more positive in lower SES groups. Unfortunately this possible attitudinal advantage for lower SES girls is rarely translated into opportunity since, being

from a lower socioeconomic group, has been repeatedly shown to be more of a handicap to educational attainment for women than for men (Alexander and Eckland, 1974).

Effectance Motivation in Mathematics

Effectance motivation refers to a theoretical concept first advanced by White (1959) which has gained considerable acceptance since. Effectance is ". . . inferred specifically from behavior that shows a lasting focalization and that has the characteristics of exploration and experimentation, . . . it is selective, directed, and persistent, . . . instrumental acts will be learned for the sole reward of engaging in it." (White, 1959, p. 323). This attitude has to do with the joy of doing mathematics, working math puzzles for the fun of doing them and feeling great satisfaction in solving math problems. Educators call effectance motivation by another name, i.e., intrinsic motivation, which is believed to be a high level motivation that leads to high level cognitive processes. Some have hypothesized that females often lack this type of motivation in mathematics. Kagan (1964) believes that females are not involved in problem-solving in the academic areas as highly as are males. As one moves through school, problem-solving in mathematics assumes a higher and higher degree of importance. Thus, if females as a group have less motivation to solve problems, they will elect to study math less and also not learn it as well. Although the theory is clear, the NSF study did not support it. No significant differences were found in effectance motivation with the exception of one analysis in which females scored higher on the scale.

Usefulness of Mathematics

One longitudinal study found a parallel development of sex-related differences in mathematics achievement and the opinion of females that mathematics skill had little relevance to their future plans (Hilton & Berglund, 1971). These authors

concluded that sex-related difference in achievement could be partly accounted for by the growing conviction by girls that the study of mathematics had little real usefulness. Certainly usefulness is a reality factor. Mathematics is not particularly easy to learn for most people. Why learn it if it has no use? At two of the four NSF schoosl boys perceived mathematics as significantly more useful than did girls providing support for the idea that knowledge of usefulness of a subject is important.

The pattern of significant sex-related difference found in the affective variables in the NSF study is important. At Schools 1 and 4 where significant differences in math achievement were found, significant differentes on 5 or 6 of the affective factors were found. Certainly this pattern of sex-related learnin differences in attitudes in conjunction with sex-related differences in mathematics suggest that a matrix of social/cultural factors influences strongly females' learning of mathematics.

In the 1975 NSF study, informtions was also gathered about the characteristics of students electing to continue the study of mathematics (Sherman & Fennema, in press). Students in the 10th and 11th grades were asked to indicate whether or not they intended to study mathematics the next year. Since they responded about the same time they were officially selecting classes for the following year, the data were fairly reliable. As might be expected, those who intended to continue their study of mathematics scored significantly higher on math achievement. In general, more boys than girls intended to continue. However, this was particularly true of boys in the lower half of their class on math achievement. All other variables appeared to differentiate about equally between boys and girls who did and did not intend to continue their study of mathematics. Covarying out the effects of cognitive factors generally confirmed these results as did a comparison of students enrolled and not enrolled in mathematics.

It appears that while the variables associated with continuing to study mathematics were much the same for both sexes, the fact that males had more positive attitudes towards mathematics in some fairly specific ways helps to explain why the percent of males who continue to study mathematics is higher than any difference in achievement would predict.

Conclusions

After this lengthy and rather tortuous examination of some myths, theory, old and new empirical data, several conclusions can be drawn.

(1) Sex-related differences in mathematics achievement are not universal or even nation-wide phenomena. When previous mathematics study was controlled, males significantly out-performed females in only two schools out of four.

(2) Many fewer females than males study math in 11th and 12th grades. Sex-related differences in the studying of mathematics are prevalent with the gap between the number of males and females who do study math formally, increasing throughout schooling.

(3) The relationship between cognitive factors and differential learning of mathematics by the sexes is unclear, and more research is clearly needed. Although the study reported here gave little indication that either verbal or spatial visualization ability affected boys' and girls' learning of math differently, more data is needed on the interaction effects of these abilities, on different types of mathematics problems, as well as on mathematics learning of learners of different ages.

(4) Differential mathematics studying and mathematics achievement by the sexes, when it occurs, is at least partially caused by socio/cultural factors mediated through sex-role expectations. Lending support to the idea that perceived sex-role is a critical determiner in differential

mathematics learning by the sexes is the increasing gap in achievement and studying which occurs during the adolescent years concurrently with the increasing priority given by both males and females for development of a personally workable sex role. When sex differences in mathematics achievement were found, many sex-related differences in attitudes toward math were also found.

The variables discussed in this paper are all elements in a set. Together they, and probably some others, make up a set which could be identified as "sexual stereotyping of mathematics." By having looked at some of the elements separately, deeper understanding of the set emerges as well as the validity of the belief that the learning of mathematics is partically determined by society at large which defines and enforces sex-role standards upon all individuals. The evidence presendted here gives strength to the belief that there are no eternal "truths" of differences in cognitive ability between the sexes.

References

Aiken, L. R. Verbal factors and mathematics learning: A review of the research. Journal for Research in Mathematics Education, 1971, 2, 304-313.

Alexander, K. L. & Eckland, B. K. Sex difference in the educational attainment process. American Sociological Review, 1974, 39, 668-82.

Astin, H.S. Sex differences in mathematical and scientific precocity. in Stanley, J.C., D. P. Keating, and L. H. Fox (eds.) Mathematical Talent: Discovery, Description and Development. Baltimore, Johns Hopkins University Press, 1974, 87-100.

Block, J. H. Conceptions of sex role: Some cross-cultural and longitudinal perspectives. American Psychologist, 1973, 28, 512-526.

Callahan, L. G. & Glennon, V. J. Elementary School Mathematics: A Guide to Current Research. 1975, Washington, D.C., Association for Supervision and Curriculum Development.

Crandall, V. J., W. Katkovsky and A. Preston. Motivational and ability determinants of young children's intellectual achievement behaviors. Child Development, 1962, 33, 643-661.

Fennema, E. Mathematics learning and the sexes: A review. 1974. Journal for Research in Mathematics Education, 5: 126-139.

Fennema, E. Mathematics, spatial ability and the sexes. In Fennema, E. (ed.) Mathematics Learning: What Research Says about Sex Differences, ERIC/SMEAC, in press.

Fennema, E. and Sherman, J. Sex-related differences in mathematics achievement, spatial visualization and socio-cultural factors. Submitted for publication to American Educational Research Journal, in pressa.

Fennema, E. and Sherman, J. Instruments designed to measure attitudes toward the learning of mathematics by females and males. Submitted for publication to Journal Supplement Abstract Service, in pressb.

Frieze, I. A. Women's expectations for and causal attributions of success and failure. In Mednick, M. T. S., Tangri, S. S. and Hoffman, L. W. (eds.) Women and Achievement: Social and Motivational Analyses, 1975, New York, Wiley, 158-169.

Hilton, J. L. and G. W. Berglund. Sex differences in mathematics achievement. Educational Testing Service, Princeton, NJ, 1971.

Horner, M. Sex differences in achievement motivation and performance in competitive and non-competitive situations. Unpublished doctoral dissertation, University of Michigan, 1968.

Horner, M. Achievement-related conflicts in women. In Mednick, M. and Tangri, S. (eds.). New Perspectives on Women. Journal of Social Issues, 28, 1972, 157-175.

James, G. and James, R. C. Mathematics Dictionary, 3rd edit., 1968, Princeton, NJ, Van Nostrand.

Kagan, J. Acquisition and significance of sex typing and sex role identity. from Hoffman, M. L. and L. W. Hoffman (eds.). Review of Child Development Research, 1964, New York, Russell Sage Foundation, 137-167.

Krathwohl, D. R., Bloom, B. S., Masia, B. B. Taxonomy of Educational Objectives: Handbook II: Affective Domain, 1964, New York, David McKay.

Maccoby, E. E. Sex differences in intellectual functioning. In Maccoby, E. E. (ed.) The Development of Sex Differences, 1966, Stanford, California, Stanford University Press, 24-55.

Maccoby, E. E. and C. N. Jacklin. Sex differences in intellectual functioning. In Assessment in a Pluralistic Society. Proceedings of the Invitational Conference on Testing Problems. Educational Testing Service, Princeton, NJ, 1973, pp. 37-55.

Maccoby, E. E. and C. N. Jacklin, 1974. The Psychology of Sex Differences. Stanford, California, Stanford University Press.

Mathews, B., Assistant to the Vice Chancellor, University of Wisconsin--Madison, personal communication, January 1976.

Mednick, M. T. S. and H. J. Weissman, The psychology of women--selected topics. Annual Review of Psychology, 26, 1975, 1-18.

Meyer, W. J. and Thompson, G. G. Sex differences in the distribution of teacher approval and disapproval among sixth-grade children. Journal of Educational Psychology, 47:4 1956, 385-396.

Miles, P. E. Associate Chair and Professor, Department of Mathematics, University of Wisconsin--Madison, personal communication, January 1976.

Mullis, I. V. S. 1975. Educational Achievement and Sex Discrimination, Denver, Colorado 80203. 700 Lincoln Tower, National Assessment of Educational Progress.

Osen, L. M. Women in Mathematics, 1974, Cambridge, Massachusetts, Massachusetts Institute of Technology.

Sells, L. W. High school mathematics as the critical filter in the job market. Mimeographed paper, March, 1973.

Sears, P. S. and Feldman, D. H. Teacher interactions with boys and girls. National Elementary School Principal, 46:2, 1966, 30-35.

Sherman, J. A. Problem of sex differences in space perception and aspects of intellectual functioning. Psychological Review, 1967, 74 (4), 290-299.

Sherman, J. A. On the Psychology of Women: A Survey of Empirical Studies. Springfield, Illinois, Charles C. Thomas, 1971.

Sherman, J. and Fennema, E. The study of mathematics by high school girls and boys: related variables. Submitted for publication to American Educational Research Journal.

Smith, I. M. Spatial Ability, Knapp, San Diego, 1964.

Stafford, R. E. Hereditary and environmental components of quantitative reasoning. 1972. Review of Educational Research, 42:2, 183-201.

Stein, A. H. and M. M. Bailey. The socialization of achievement orientation in females. Psychological Bulletin, 1973, 80 (5), 345-366.

Stein, A. H. and J. Smithells. Age and sex differences in children's sex-role standards about achievement. Developmental Psychology. 1969, 1, (3) 252-259.

Torrance, E. P. Changing reactions of pre-adolescent girls to tasks requiring creative scientific thinking. Journal of Genetic Psychology. 1963, 102, 217-223.

White, R. W. Motivation reconsidered: The concept of competence motivation. Psychological Review, 1956, 66, 297-333.

Scannell, D. P. Test of Academic Progress: Mathematics, Houghton Mifflin, 1971.